Establishment of Performance related Specifications using Pay Factors and Relationship between Fatigue Cracking and Pay Factors

Sang-Min, Hwang . Suk-Keun, Rhee . Seong-Min, Kim . Sung-Lin, Yang
Department of Civil Engineering, Kyung Hee University, 1 Seocheon, Kiheung, Yoingin, Kyunggi 446-701, Korea
Jsddd23@hanmail.net

ABSTRACT

This study aims to address the development of performance based payment adjustment methods. First, this study describes the cases in which the pay adjustment has been applied and influential factors used in forty states of U.S. Based on those preliminary studies, it has been determined that the applicable factors that can be used for the pay adjustment of asphalt pavements in Korea. This study develops a more systematic and reliable algorithm that can be trusted by both builder and vendee. The percent within limit (PWL) has been analyzed as a rational estimation and measurement tool for asphalt pavements. The correlation between fatigue cracking and pay adjustment factors has also been investigated in this study. The fatigue life was increased or decreased due to changing asphalt content, density and gradation.

1. INTRODUCTION

Recently, Korea has spent a considerable budget and effort on the road pavement. However, since the quality of product is rarely standardized, significant and inconsistent expense costs to maintain and utilize the pavement after completion. Because of insufficient data, lowering and unpredictable quality of the final product is frequently observed and considered problematic in terms of management and maintenance on the road pavement. The budget for the pavement maintenance was almost up to 20% of total budget of road construction per year.

On the other hand, many european nations and U.S states have focused on efficient and effective management of the road for performance in the field of road pavement, establishing performance related specifications for maintenance and operation. Besides, U.S. states strictly manage the road construction applying pay adjustment for the pavement design and construction to maintain road performance. About 40 states of the U.S. adopted pay adjustment, applying their own factors which affects on the performance greatly such as density or asphalt content.

Thus this research was performed to select the applicable factors that are considered for pay adjustment of asphalt road pavement in Korea. Rational estimation and measurement tools for the

payment of asphalt road management and operation are also suggested. This study also has been analyzed of the correlation between fatigue cracking and pay adjustment factors to expect the fatigue life due to changing pay adjustment basic factors.

2. PRESENT PAY ADJUSTMENT IN U.S.

Pay adjustment is universally applicable to many U.S. states based on individual specification. Furthermore, pay factor is estimated by PWL method, are measurement tools for payment of asphalt road management to apply probability theory. AASHTO proposes Pay Factor as a equation like P.F=55+0.5PWL(percentage within limit).

U.S. states adopt the pay adjustment based on almost 8 basic factors, including density. In the case of the density is most frequently used among the pay adjustment basic factors, it has been used as a basic factor in 32 U.S. states. Also, the asphalt content has been used in 30 U.S. states including Florida. Especially there are 8 states including Minnesota that has been adopting pay adjustment about superpave method.

On the other hand, most U.S. states rarely adopt the thickness as a pay adjustment basic factor, whereas korea agency adopt the thickness for the inspection provision to accept the road pavement construction. Figure 1 explains the frequency of application.

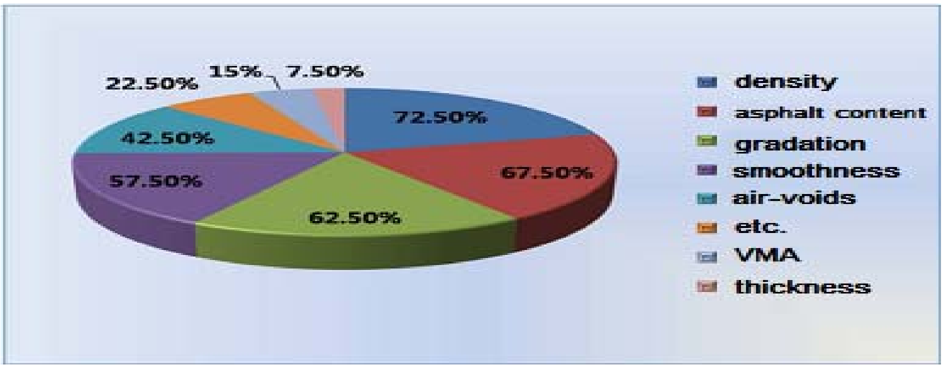

FIG 1. Frequency of application of pay adjustment factors

3. SELECTING PAY ADJUSTMENT FACTORS

The performance of asphalt mixture can be forecasted by some factors such as asphalt binder content, in-place density, air-voids, gradation and VMA. Therefore, the analysis of factors with regard to asphalt binder contents, air voids is very important procedure to evaluate the pavement performance, and the most critical factor to affect the asphalt pavement These factors can be classified by three standardization as following Table 1

Table 1 Influence factors to performance of asphalt road pavement

Division	Factors
Quality Management Factors	In-place density, Air-voids, Asphalt Binder Contents, VMA, Gradation
Permit for Completion Factors	Thickness, Smoothness
Construction Management Factors	Temperature

43 U.S. states have been applied pay adjustment stand on pay factor, managing the pay adjustment basic factors which affect road pavement performance. Generally, final payment is figured out by composite pay factors according to the D.O.T. provisions depending on two or four pay adjustment basic factors. This is called "composite pay factor". On the other hand, Korea has been only applied thickness and smoothness as completion permit. This means excluding factors which affect pavement quality such as the density and the asphalt content. Thus we assumed five pay adjustment standard factors(asphalt binder content, In-place density, gradation, thickness, smoothness), considering the interior permit completion and influence on the pavement quality which is frequently used in the U.S.

4. SELECTING QUALITY MEASUREMENT METHOD

This study was conducted to suggest reasonable quality measurement methods of asphalt pavements to be used in the pay adjustment. The pay adjustment is a method to adjust the construction cost according to the pavement quality based on the statistic theories. Many U.S states use pay adjustment and the PWL(Percent with in Limit) is calculated using their quality index tables. The PWL for a lot can be estimated by using the quality index, Q. The Q-statistic is used with a PWL table to determine the estimated PWL for the lot. A PWL table is shown in table 1. Conceptually, the Q-statistic, or quality index, performs the same function as the Z-statistic, except that the reference point is the mean of an individual sample, X , instead of the population mean, μ, and the points of interest with regard to areas under the curve are the specification limits.

$$Q_L = \frac{\overline{X} - LSL}{S} \quad \text{and} \quad Q_U = \frac{USL - \overline{X}}{S} \qquad (1)$$

Q_L = quality index for the lower specification limit

Q_U = quality index for the upper specification limit

LSL = lower specification limit

USL = upper specification limit

$\overline{X}$ = sample mean for the lot

S = sample standard deviation for the lot

QL is used when there is a one-sided lower specification limit, while QU is used when there is a one-sided upper specification limit. For two-sided specification limits, the PWL value is estimated as:

$$\textbf{TPWL=UPWL+LPWP-100} \quad (2)$$

UPWL= percent below the upper specification limit (based on *QU*)

LPWL= percent above the lower specification limit (based on *QL*)

$$\textbf{Pay Factor = 55+0.5TPWL} \quad (3)$$

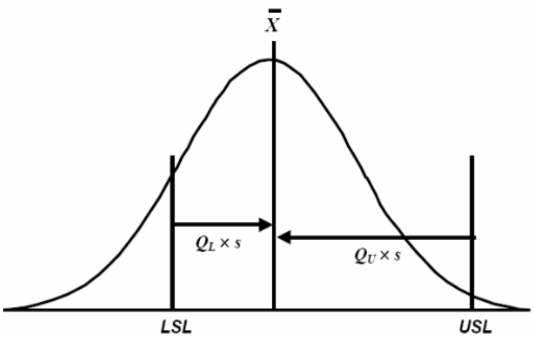

FIG 3. PWL in standard deviation (Q-Value) from the mean (Burati et al., 2003)

5. CORRELATION BETWEEN FATIGURE CRACKING AND PAY ADJUSTMENT FACTORS

5.1 Correlation between asphalt content and fatigue cracking

The test was proceeded with a controlled air voids and non-controlled air voids to avoid the effect of over compaction. Every specimen reduced its stiffness as the asphalt content increases, and the fatigue life was also reduced as the asphalt content with its stiffness at the same time, like the Figure 4 below.

(a) (b)

FIG 4. Tendency of fatigue life and stiffness from AP (a) controlled air voids, (b) non-controlled air voids

5.2 Correlation between density and fatigue cracking

Density variation was performed manufacturing specimens with the refined compaction frequency, and the result of stiffness and fatigue life was reduced as the density increases like the Figure 5 below. Especially 98% theoretical maximum density showed the highest fatigue life. That seems to be an effect of over compaction.

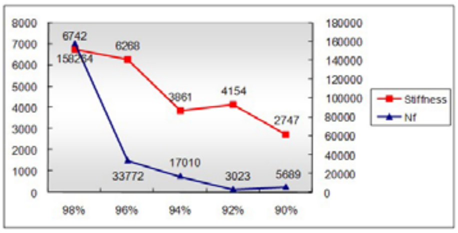

FIG 5. Tendency of fatigue life and stiffness from density

5.3 Correlation between fatigue cracking and gradation

In the case of gradation, the test was performed with a standard passing percentage #8. The five specimen was product as follow: 35% as an upper specification, 50% as a lower specification, 32% as an excluded lower limit, 53% as an excluded upper limit, and 40% as a standard passing percentage #8. The following Figure 6 is the result of this test.

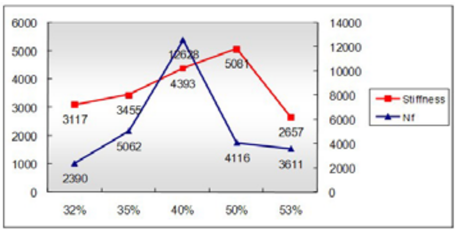

FIG 6. Analysis Tendency of fatigue life and stiffness from gradation

In the case of gradation, stiffness and fatigue life of 35% and 50% caused higher result until the fracture than those of 32% and 53% which were out of specification. Through this result, we found

that the asphalt mixture becomes fragile since it didn't correspond the limit of specification which has 40% of standard passing percentage #8.

6. CONCLUSION

- Forty U.S. states apply the pay adjustment method, using their own factors which affect performance of pavement such as density and asphalt content. The density, asphalt content, gradation and smoothness are mostly applied factors. Thus we assumed five pay adjustment standard factors, the four factors just mentioned and the thickness of the pavement.
- Many U.S states use pay adjustment and the PWL is calculated using their quality index tables. Thus we assumed that PWL was a reasonable approach to adjust pavement quality.
- We performed an indirect tensile test to analyze the relationship between fatigue cracking and pay adjustment factors. The tendency of fatigue cracking was very clear, according to the density, asphalt content, gradation.

In the case of asphalt content, every specimen reduced its stiffness as asphalt content increases, and the fatigue life was reduced as the asphalt content with its stiffness at the same time. Especially 98% theoretical maximum density showed the highest fatigue life. That seems to be an effect of over compaction. In the case of gradation, stiffness and fatigue life of 35% and 50% caused higher result until the fracture than those of 32% and 53% which were out of specification.

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